# Observing Systems and Advanced Technology
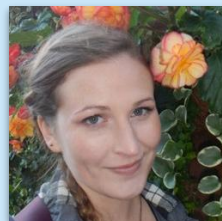
Steve Ruberg
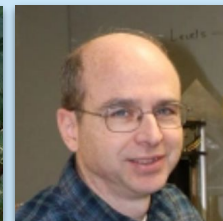Program Leader

Kyle Beadle

Steve Constant

Dennis Donahue

Lauren Marshall
Contractor

Ron Muzzi

Andrea Vander Woude

Russ Miller
Cooperative Institute for
Great Lakes Research

GLERL's Observing Systems and Advanced Technology (OSAT) branch conducts scientific and engineering research and development, identifies emerging observational infrastructure needs, and provides environmental observations and data throughout the Great Lakes.

# OSAT addresses issues identified in NOAA's research plans and guiding documents.
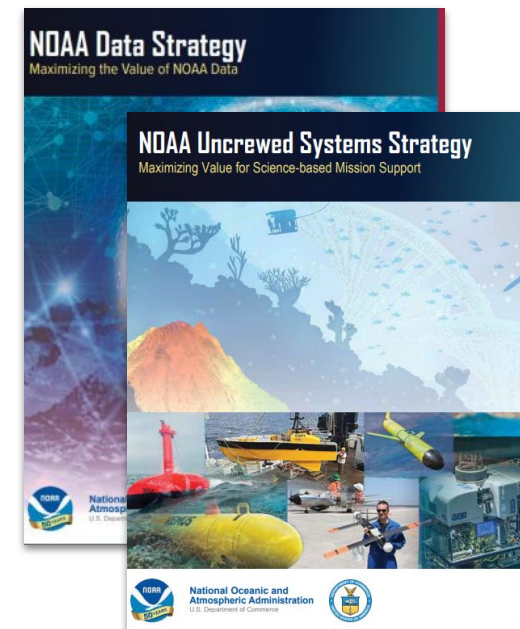


OSAT guiding principles and goals p. 27

Goals and Strategic Objectives pp. 15-19

**Delivering NOAA's future**

See review website "Documents" tab for more.

# Converting real world observations to data.

- In situ sensors and observing systems
- Direct ecosystem sampling
- Satellite and airborne remote sensing
- Mobile platforms

Observations and data on the physical, chemical, and biological components of the Great Lakes and coastal ecosystems supports studies and assessments, informs experiments and models, and ultimately predictions and forecasts.

OSAT holds a pivotal role in providing the technological and observational infrastructure that informs GLERL science. OSAT works closely with EcoDyn and IPEMF in the collection of physical, chemical, and biological observations and data that contribute to building an ecosystem understanding and provide the input needed for environmental modeling.
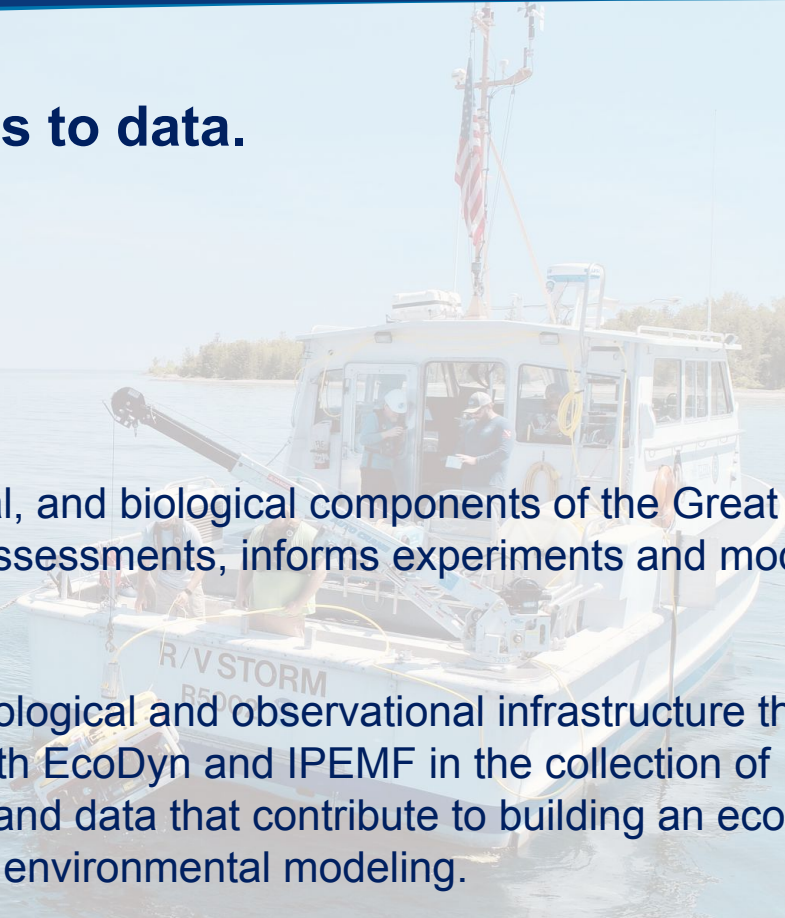
# NOAA Great Lakes Vessel Fleet

Dennis Donahue

# GLERL's Lake Michigan Field Station (LMFS) and Vessel Operations play a critical role in supporting integrated scientific research on the Great Lakes ecosystem.

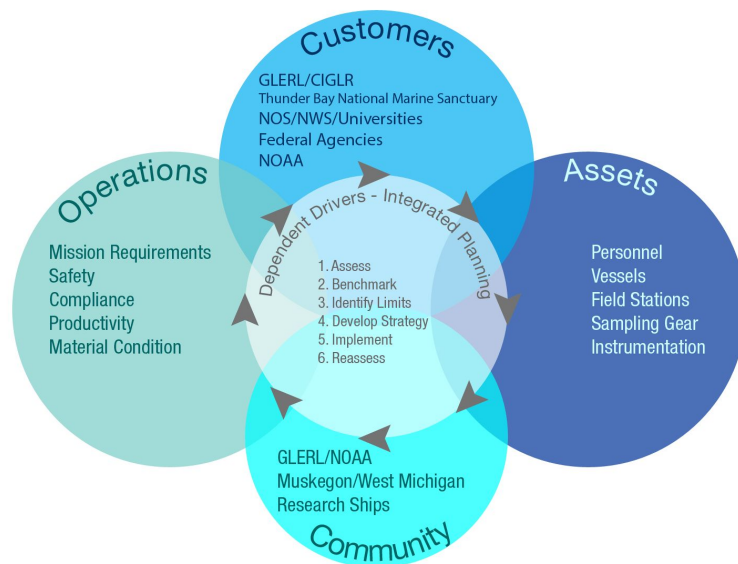Provides both small boat and deep-water docking capabilities.

Houses laboratory facilities supporting long-term ecological observations and fundamental research on ecosystem processes, and the development of models critical to understanding ecosystem structure and function.

Proximity to Lake Michigan provides the capacity to process time-critical samples immediately after collection and to sample during natural events (e.g., upwelling, spring flooding) and short weather windows during inclement periods.

# GLERL's LMFS and Vessel Operations are coordinated to provide safe, reliable, and innovative service to support integrated scientific research for NOAA and external partners.



**Customers**
GLERL/CIGLR
Thunder Bay National Marine Sanctuary
NOS/NWS/Universities
Federal Agencies
NOAA

**Operations**
Mission Requirements
Safety
Compliance
Productivity
Material Condition

Dependent Drivers - Integrated Planning
1. Assess
2. Benchmark
3. Identify Limits
4. Develop Strategy
5. Implement
6. Reassess

**Assets**
Personnel
Vessels
Field Stations
Sampling Gear
Instrumentation

**Community**
GLERL/NOAA
Muskegon/West Michigan
Research Ships



**The GLERL Vessel Crew works to:**
Support science direction - offer alternatives
Support traditional sampling - adapt to emerging technologies
Optimize platforms - maintain versatility
Accomplish current mission - anticipate future opportunities

# GLERL's Marine Superintendent provides leadership to NOAA's Small Boat Program.

- The NOAA Small Boat Program is administered through the Office of Marine Aviations (OMAO) line office and is headquartered in Seattle, Washington.

- NOAA relies on hundreds of small boats located throughout the nation.

- NOAA small boats are owned, maintained and operated by the individual line offices.

- NOAA GLERL Vessel Operations support all NOAA interests in the Great Lakes basin.

- Dennis Donahue serves as a NOAA Small Boat Safety Board member (2019 Chairperson) and the Small Boat Officer for the NOAA Oceanic and Atmospheric Research (OAR) line office.



2016: National Ocean Service Peer Recognition Rafting Award: For providing vessel and logistical support for offloading contents of a sunken oil barge in Lake Erie

**RELEVANCE:** Assess GLERL's R&D relevance to NOAA's mission & value to Nation

# GLERL's Vessel Operations Group supports all NOAA interests in the Great Lakes.

- GLERL & Cooperative Institute for Great Lakes Research (CIGLR)
  - Research Consortium Partners
- NOAA National Ocean Service (NOS)
  - Great Lakes National Marine Sanctuary Programs
  - National Centers for Coastal Ocean Science (NCCOS)
  - Office for Coastal Management (OCM)
  - Office of Response and Restoration (OR&R)
  - Office of Coast Survey (OCS)
  - Mussel Watch Program
  - NOAA Lake Superior National Estuarine Research Reserve
- National Weather Service (NWS)



RV *Storm* docked in front of the offices of NOAA Thunder Bay National Marine Sanctuary located in Alpena, MI on Lake Huron.

# The NOAA GLERL vessel fleet supports partners around the region.



Full season vessel base     Transient vessel base

# GLERL's Largest Vessel: SRV Laurentian

**Features**

- Built 1974 - University-National Oceanographic Laboratory System (UNOLS)
- Operated by GLERL since 2002
- 80ft Multi-discipline platform
- 20 day duration
- 14 berths
- Heavy lift and trawl capable
- Limited ice capabilities
- Fueled by B100 Biodiesel

**Primary platform for GLERL programs**

- Long Term Research monitoring
- Spatial studies
- Plankton Survey System (PSS)
- Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS)
- Fishery Acoustics
- Winter operations
- Outreach and education

**Supports NOAA regional missions**

- Deep water hydrographic surveys
- Archeological exploration
- National Data Buoy Center (NDBC) buoy support
- Hydrographic and Benthic Habitat mapping
- Cultural asset exploration



United States Department of Commerce // National Oceanic and Atmospheric Administration // Great Lakes Environmental Research Laboratory

11

# Class II Vessels (26-40')



**Features**
- Hydro survey capable
- Side scan / Multi-beam sonar capable
- Alternating current and hydraulic power

**Supports**
- Near shore support / sampling
- Dive operations
- Event response
- Remote research locations
- Hydrographic and Benthic Habitat mapping
- Cultural asset exploration

**Vessels are converted to science missions by the Lake Michigan Field Station staff.**

# Class III Vessels (41-65')



**Features**
- Heavy lift
- High speed
- Transient and logistic advantages
- Dive support
- Multi-beam survey platforms
- Side scan sonar
- Onboard survey processing

**Supports**
- Real-time Coastal Observation Network (ReCON) and Great Lakes Observing System (GLOS) buoys
- HABs ESP
- Event response
- Sanctuary mooring buoys
- NOAA Thunder Bay National Marine Sanctuary initiatives
- Hydrographic and Benthic Habitat mapping
- Cultural asset exploration
- Autonomous vehicle support

# Ann Arbor Facility and Observing Equipment

Kyle Beadle
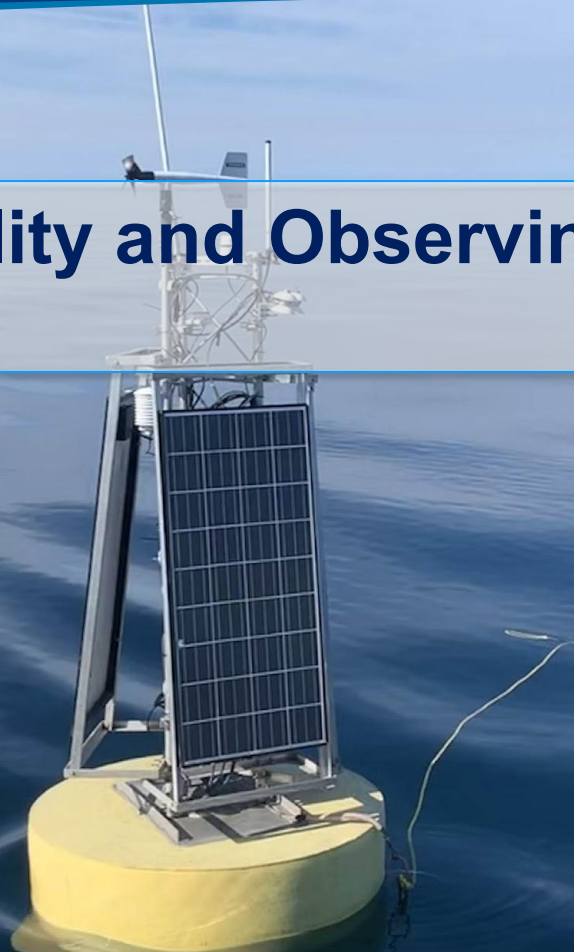
# The GLERL Ann Arbor facility is fully equipped, adaptable, and resilient toward advancing NOAA's mission of science, service and stewardship.



**Ware Yard**

**High Bay**

**Marine Instrumentation Lab**

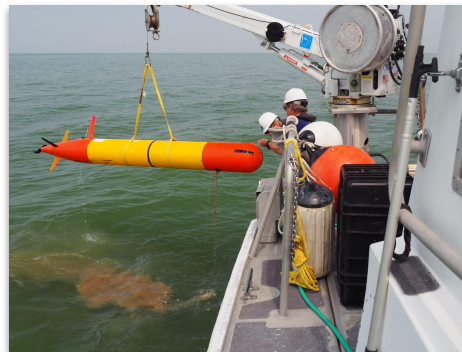# GLERL has been a leader in adapting and evolving instruments for Great Lakes research over the last 40 years.
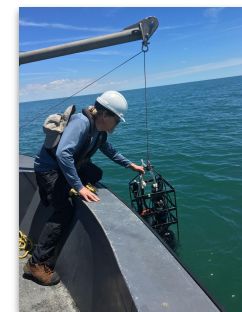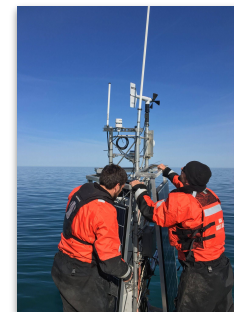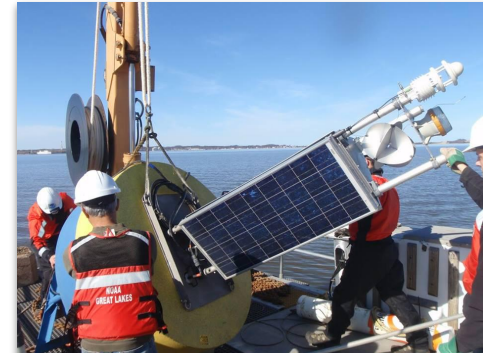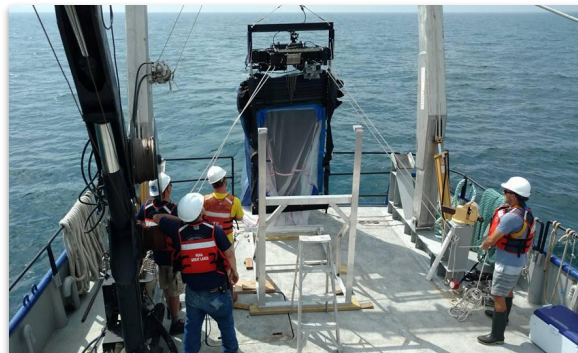
**AUVs provide detailed spatial and temporal patterns of riverine inputs, thermal structure, and lower food web structure to support lake-scale ecological forecasting and GLERL's Long-term research programs.**



Slocum Glider



Wave Gliders



Long-range Autonomous Underwater Vehicle



SeaTrac

**PERFORMANCE:**
Assess overall effectiveness of GLERL's plans & R&D in meeting NOAA's Strategic Plan objectives & Nation's needs

# GLERL develops and uses new instruments to meet our changing needs in addressing important scientific questions.

Marine Instrumentation Laboratory capabilities:

- Electronic & mechanical design
- Software development
- Electronic/electrical construction
- Mechanical construction & assembly
- Prototype development
- Testing, diagnostics, & calibration
- Mooring design & fabrication
- System assembly (buoys, platforms, etc.)
- Handling and storage
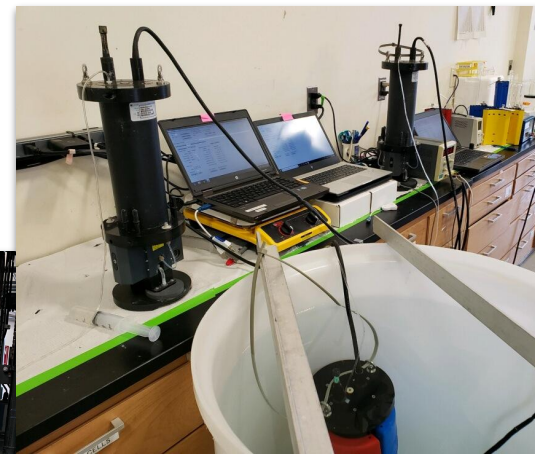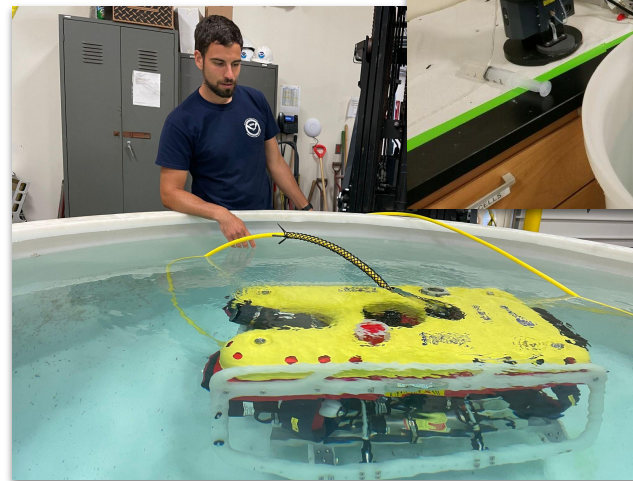
Above: Calibrating nutrient sensors GLERL's High Bay.

Left: Preparing a remotely operated vehicle (ROV) for fieldwork.

RELEVANCE:
Assess GLERL's R&D relevance to NOAA's mission & value to Nation

# Collaborating to advance ecosystem measurement strategies and technologies.

Co-hosted the Marine Technology Society Buoy Workshop with the Cooperative Institute for Great Lakes Research (CIGLR), and the Great Lakes Observing System (GLOS) April 19-20, 2018.

The workshop is held bi-annually to review the state-of-the-art in moored observing system capabilities.

This was the first ever Great Lakes hosted MTS workshop. There were 115 attendees from around the world. Meetings were held on the University of Michigan campus and we conducted a tour of the GLERL Ann Arbor facility.

# Data

Steve Constant

QUALITY: Assess quality of GLERL's R&D

# Increasing the accessibility, use, and synthesis of NOAA Great Lakes data.

- Real-time
- Moored data
- Autonomous
- Shore-based
- Ship-based
- Satellite
- Airborne
- Uncrewed

**Observations**

**Sample Collection**
remove from environment

**Sensor**
measure in environment

**Remote Sensing**
measure at distance from environment

**Data**

+ Location & Time

# Managing data

# Online Data Access

# Great Lakes CoastWatch Node

Andrea Vander Woude

# Great Lakes specific algorithms are needed for satellite retrieval of key parameters.

- Ocean algorithms often do not work well in time or space on the Great Lakes.
- Ocean algorithms often are not tuned to the parameters Great Lakes stakeholders need (e.g. ice types, chlorophyll).
- Vast difference in resolution and spatial coverage needs.
- Freshwater vs. saltwater.

**NOAA CoastWatch Regional Nodes**

Great Lakes Node
Ann Arbor, MI

East Coast Node
Annapolis, MD

PolarWatch Node
West Coast Node
Santa Cruz, CA

Central Node
College Park, MD

Central Pacific Node
Honolulu, HI

Gulf Coast Node
Stennis, MS

Caribbean/Atlantic
OceanWatch Node
Miami, FL
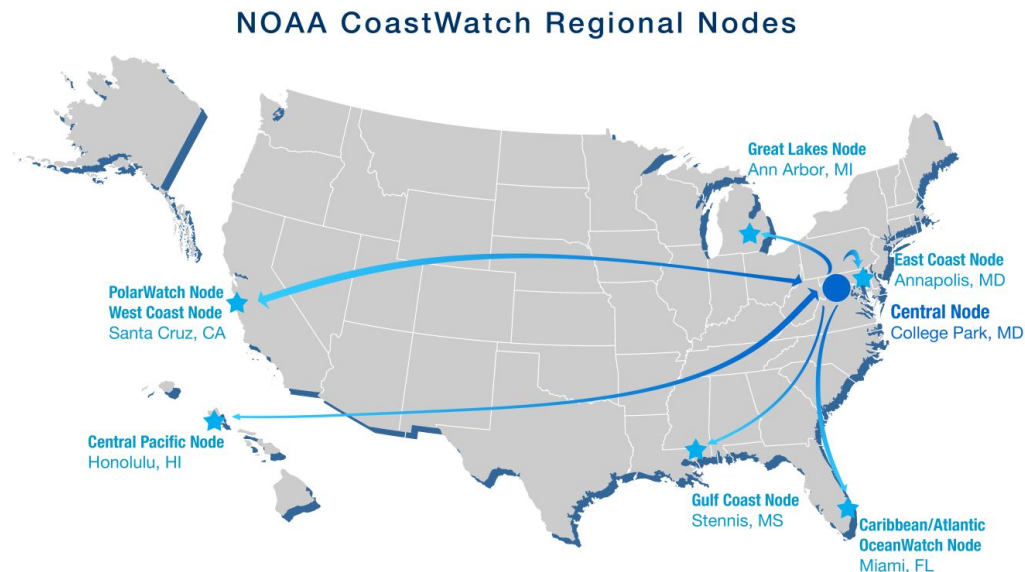
# The Great Lakes CoastWatch node advances NOAA's priority to lead the world in earth system observations and weather predictions - delivering to public, private and academic sectors.

**UNIQUE DATASETS**

*Accessible through Great Lakes CoastWatch ERRDAP or THREDDs servers.*

- Great Lakes Surface Environmental Analysis (GLSEA)
- Color Producing Agents (CPAs)
- ICECON Ice Type Classification

**NEW DATASETS & IMPROVEMENTS**

- Great Lakes Surface Environmental Analysis (GLSEA) Improvements
- GOES 16
- Great Lakes VIIRS True Color
- Satellite altimeter database products
  - (Available Fall 2021)
- Airborne Hyperspectral Imagery
  - (NOAA National Centers for Environmental Information (NCEI)  2021)
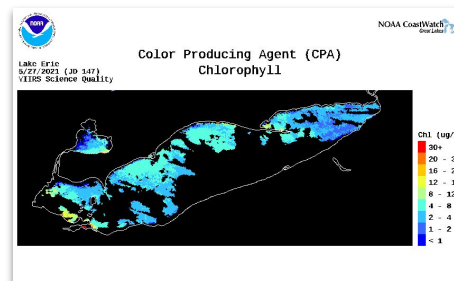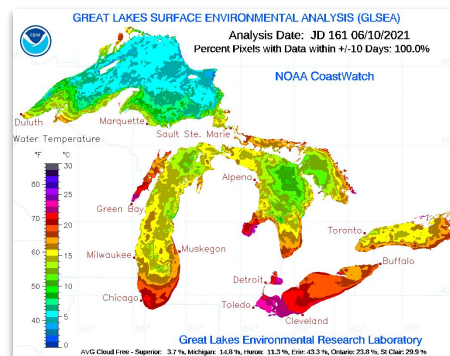
# Satellite and airborne remotely sensed data provides accurate, synoptic retrievals of key Great Lakes parameters.



**Satellite Color-Producing Agent Algorithm:**
For EPA Great Lakes National Program office decision making and HAB areal extent.
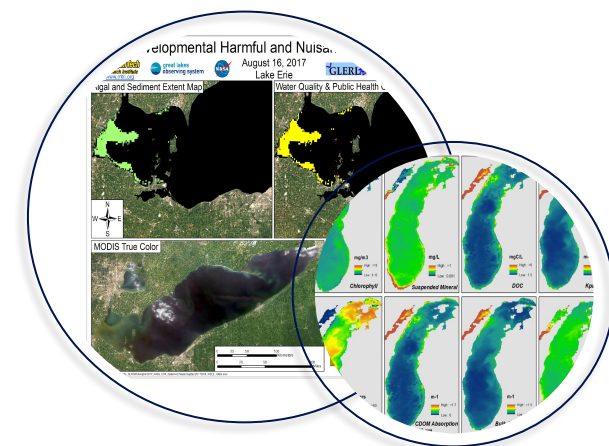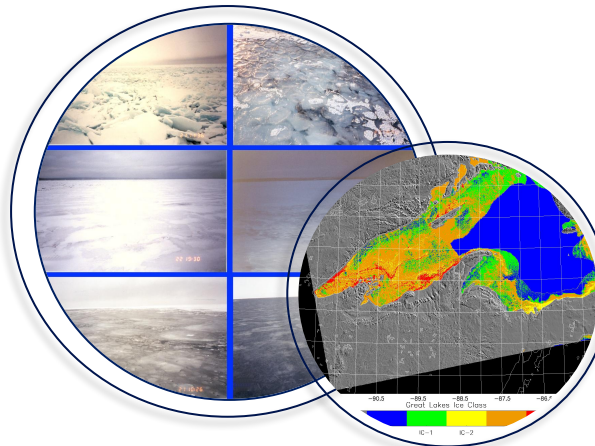
**Radar Satellite Ice-type Algorithm**
Provide data to U.S. Coast Guard for ice-breaking operations.
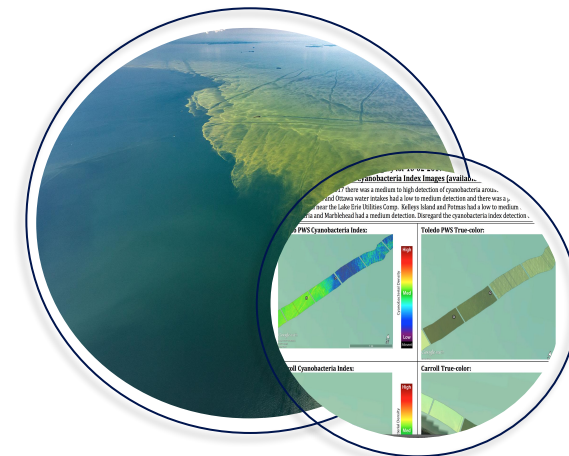
**Hyperspectral Imagery - Phytoplankton Community Composition Algorithm:**
Warn drinking water intake managers.

Sayers, **Ruberg, Leshkevich** et al., 2019, *Journal of Great Lakes Research*.

**RELEVANCE:** Assess GLERL's R&D relevance to NOAA's mission & value to Nation

# Color Producing Agents Algorithm (CPA-A)

- Developed by Michigan Tech Research Institute and GLERL for operational use under the Great Lakes CoastWatch node.
- Uses imagery from multiple satellite sensors (*MODIS, VIIRS, etc) to estimate concentrations of chlorophyll, dissolved organic carbon, and suspended minerals.
- Transitioned into use under the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) CoastWatch Great Lakes node in 2018.
- Science quality data available up to two weeks post observation; real-time time data available Summer 2021.
- Uses:
  - Create maps of of harmful algal bloom extent.
  - Addressing data gaps: e.g. EPA Great Lakes National Program Office long term monitoring program uses to fill in the gaps between spring and summer cruise in situ data collection.



**MODIS Derived Water Quality Products Suite**
May 2018 Monthly Average Products for Lake Michigan
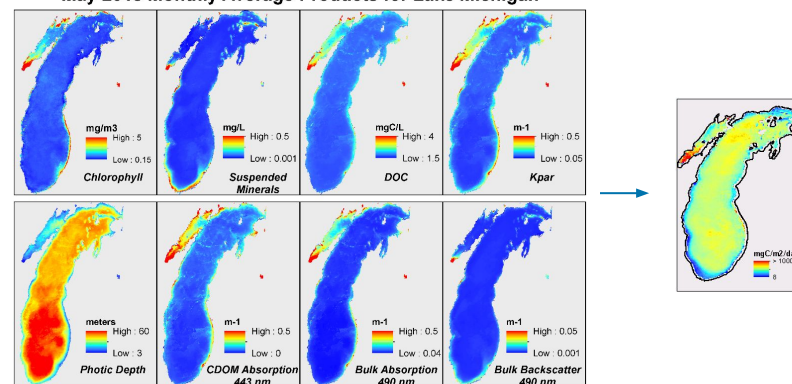
Additional applications:
- NOAA GLERL: biophysical modeling, efforts to estimate river plume and resuspended nutrients, field data collection planning
- Michigan Department of Natural Resources:  fish community responses to changes in chlorophyll (CHL) and suspended minerals (SM)
- Ohio Department of Natural Resources: and Ohio State University use CPA CHL correlated with fish trawls
- U.S. Fish & Wildlife: Green Bay fish trawl and CHL concentration
- U.S. Army Corps of Engineers: southern Lake Huron resuspension events impact on water quality (nutrient model using machine learning  with citizen science)
- Environmental Protection Agency: Lake Superior Coordinated Science Monitoring Initiative (CSMI) (CHL, SM, colored dissolved organic matter (CDOM), primary productivity

# Observing current ice cover conditions helps to improve predictive models.

**Great Lakes CoastWatch node**
Great Lakes ice observations statistics are particularly popular with stakeholders and the media. GLERL obtains, produces, and delivers environmental data and products for near real-time observation of the Great Lakes to support environmental science, decision making, and supporting research. This is achieved by providing access to near real-time and retrospective satellite observations and in-situ Great Lakes data.

**Great Lakes Surface Environmental Analysis** is a digital map of the Great Lakes surface water temperature and ice cover which is produced daily at GLERL. The lake surface temperatures are derived from NOAA polar-orbiting satellite imagery.

These products help to improve predictive models and support water-dependent industries such as hydropower, fishing, commercial shipping, and search and rescue operations.
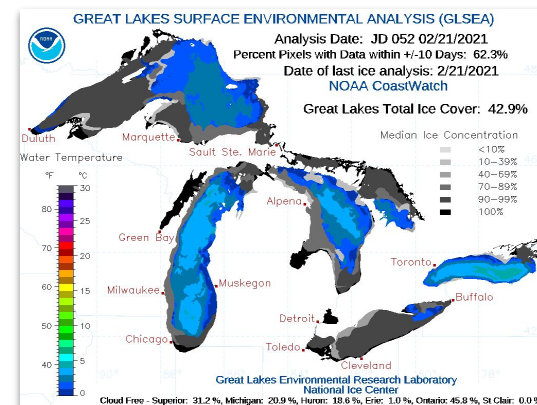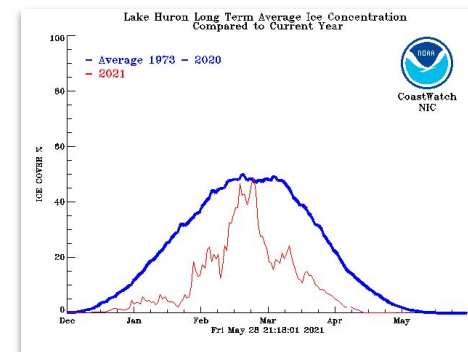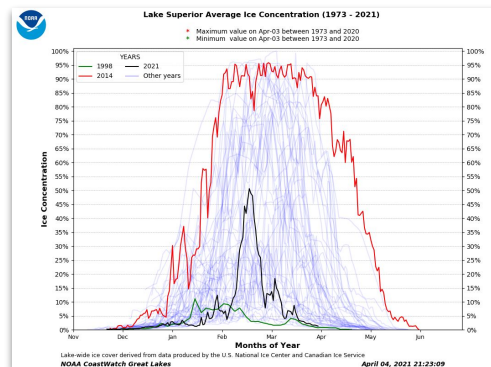
**RELEVANCE:**
Assess GLERL's R&D relevance to NOAA's mission & value to Nation

# ICECON Ice type classification is imperative for U.S. Coast Guard ice breaking operations in the Great Lakes.

Great Lakes-specific algorithm to create image product.

Visual index developed for the U.S. Coast Guard to aid ice breaking operations & commercial navigation.

Colors represent different ice types & thickness ranges.

Transitioned to operations at NOAA/NESDIS in 2017.
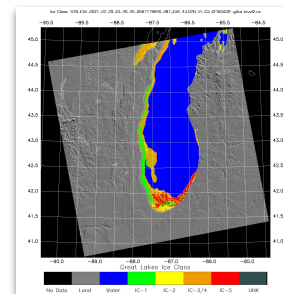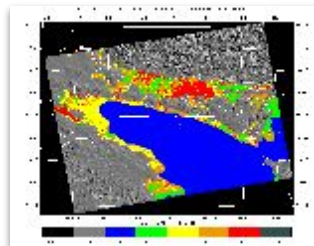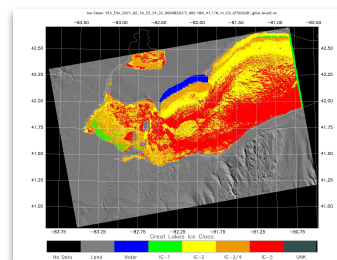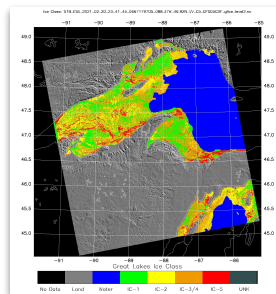


### Award-winning R2O!



George Leshkevich received a National Ice Center Medallion during the North American Ice Service (NAIS) Annual Meeting at the U.S. Coast Guard Academy  in September 2018.

**PERFORMANCE:** Assess overall effectiveness of GLERL's plans & R&D in meeting NOAA's Strategic Plan objectives & Nation's needs

# Great Lakes CoastWatch products are widely used by stakeholders.

- Support GLERL internal research projects.
- Support operational mandates within NOAA and sister agencies.
- Support regional users:
  - Environmental science
  - Decision making
  - Research
- Support educational and recreational activities.

- National Aeronautics and Space Administration
  - Goddard Space Flight Center
  - Glenn Research Center
  - Jet Propulsion Laboratory
- Michigan Tech Research Institute
- Upstate Freshwater Institute
- Cooperative Institute for Great Lakes Research (University of Michigan)
- United States Coast Guard
- Canadian Coast Guard
- Environmental Protection Agency - Great Lakes National Program Office
- NOAA National Environmental Satellite, Data, and Information Service
- NOAA National Centers for Environmental Prediction
- United States Geological Survey
- Environment and Climate Change Canada
- Oregon State University
- Ohio State University
- Nansen International Environmental and Remote Sensing Centre

# Observing Systems Program Highlights

Ron Muzzi, Kyle Beadle, Russ Miller, Steve Ruberg

# Great Lakes Meteorological Real-time Coastal Observation Network (ReCON) provides sustained critical observations for long-term research and operations.

**RELEVANCE:** Assess GLERL's R&D relevance to NOAA's mission & value to Nation



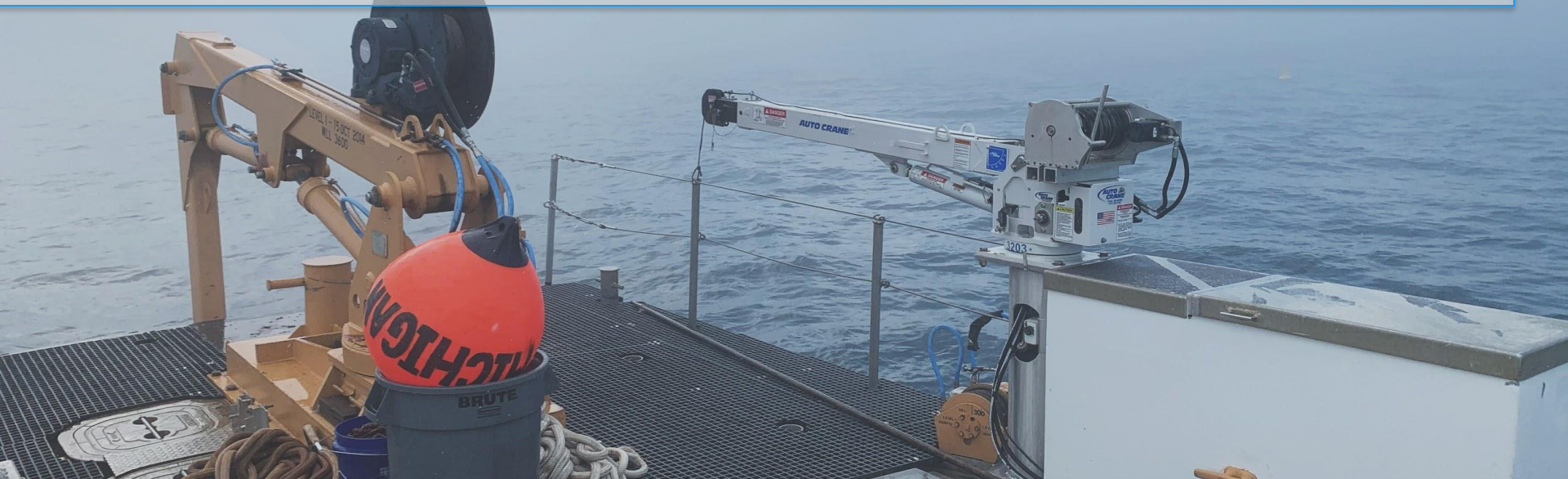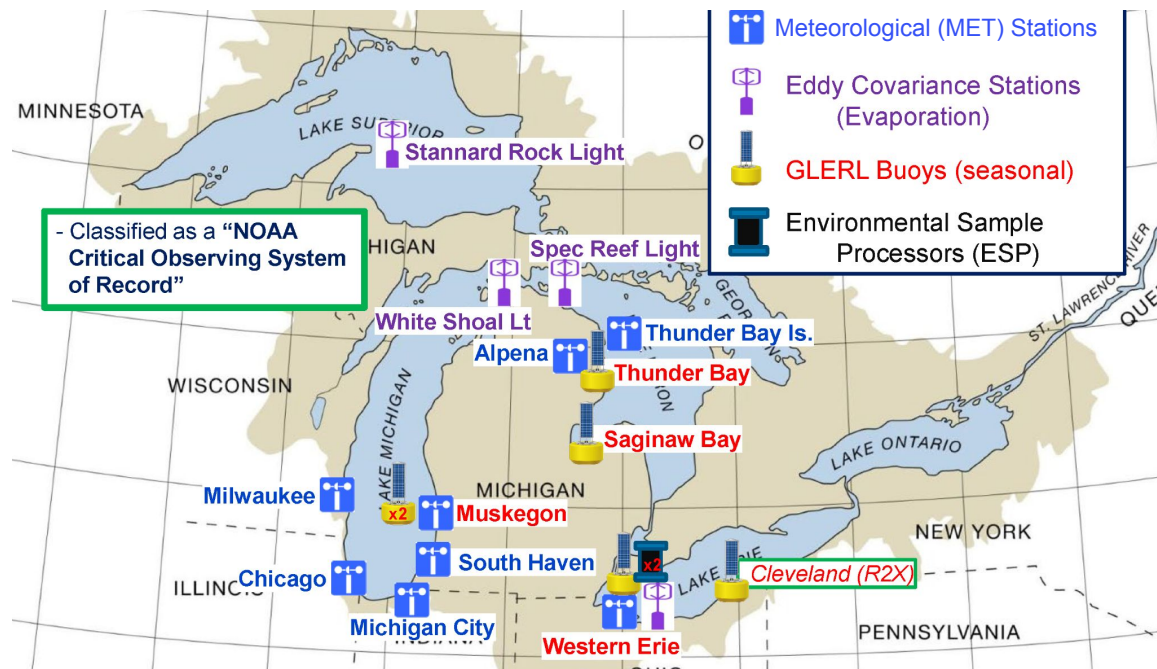- Classified as a **"NOAA Critical Observing System of Record"**

Legend:
- Meteorological (MET) Stations
- Eddy Covariance Stations (Evaporation)
- GLERL Buoys (seasonal)
- Environmental Sample Processors (ESP)

Map labels: Stannard Rock Light, Spec Reef Light, White Shoal Lt, Alpena, Thunder Bay Is., Thunder Bay, Saginaw Bay, Milwaukee, Muskegon, South Haven, Chicago, Michigan City, Western Erie, Cleveland (R2X)

# ReCON provides advanced data collection platform from buoys, underwater hubs, fixed structures, and coastal locations.

- Developed in partnership with CIGLR, U. Toledo Lake Erie Center, NOAA Thunder Bay National Marine Sanctuary, U.S. Coast Guard 9th District.
- Provides environmental data to federal, state and university researchers, educators and resource managers through a web-based data interface.
- Data available through: GLERL website, National Data Buoy Center (NDBC) website and THREDDS server, Great Lakes Observing System (GLOS) data portal.

About the system:
- Buoys operate seasonally; fixed platforms and Lake Erie Underwater Hub operate year round.
- Primarily powered by solar (wind or A/C when available).
- Embedded Linux platform for data processing, control, and diagnostics.
- Sensors include: meteorological (MET), air/water quality, radiation, acoustics, image/video.
- Guest ports allow platform use by others.
- Multiple communications options provides high bandwidth, real-time data from seafloor back to laboratory.   ✓ **Only system in the Great Lakes with this capability.**
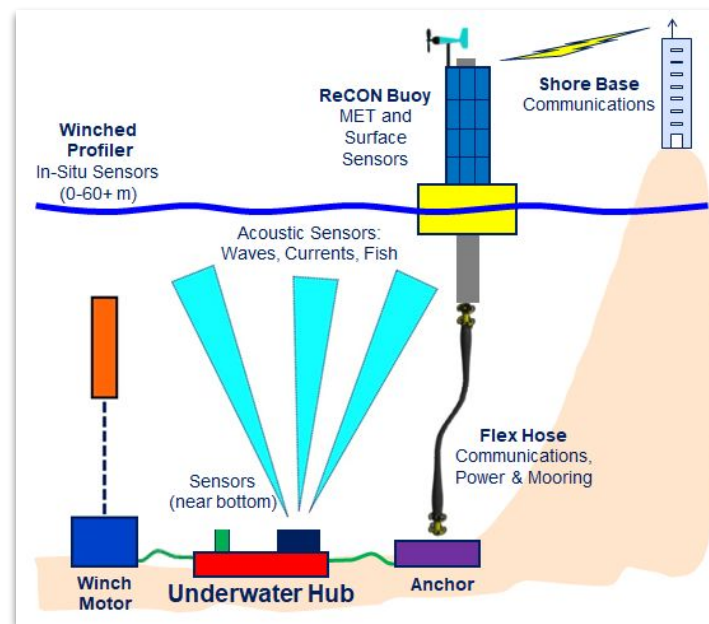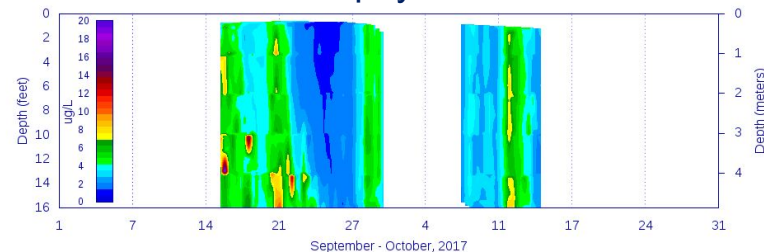
# Lake Erie Underwater Hub provides key observations year round.
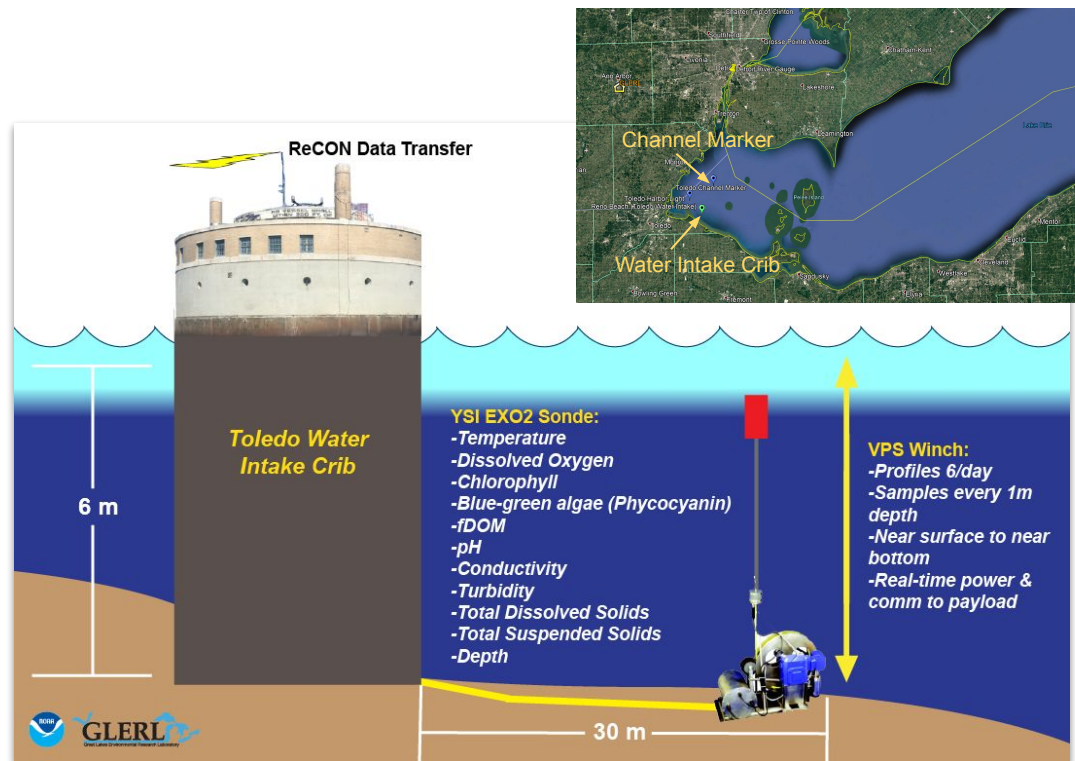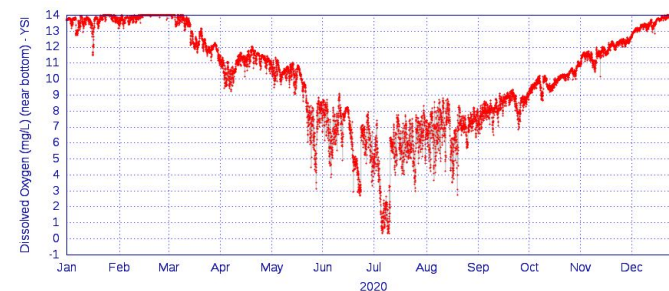
# Engineering accomplishment: Ecosystem observations fisheries acoustics and video.

- With the success of ReCON in the Great Lakes, OSAT collaborated with Atlantic Oceanographic and Meteorological Laboratory (AOML) to demonstrate an Ecosystem Observing System in the Florida Keys National Marine Sanctuary.
- The station advanced observational technology by deploying a real-time bio-acoustics system deployed with supporting physical and biological sensors to create an Ecosystem Observing station.
- This station is now being used to support GLERL's Long-Term Research (LTR) on Lake Michigan.
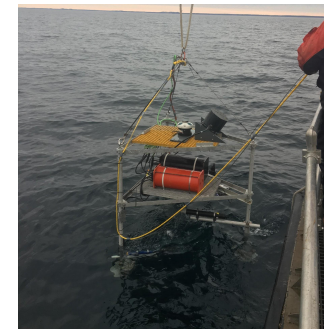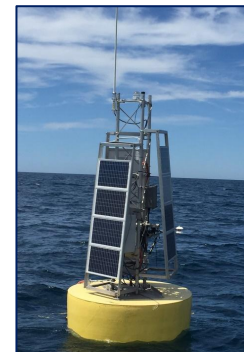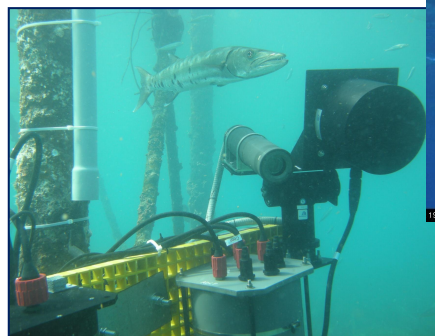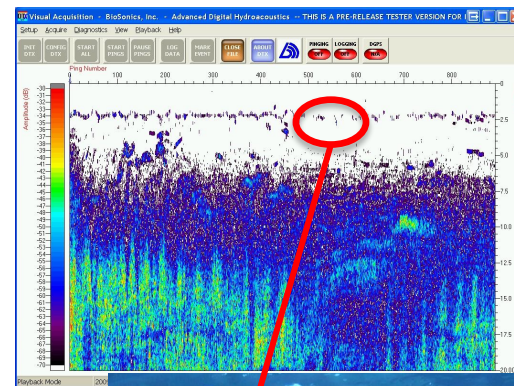


Florida Keys      →      Lake Michigan

# ReCON Engineering Accomplishment: Tracking invasive mussel activity and colonization.

**Invasive Mussel Cam**

Lake Michigan Muskegon M45 Buoy

- In-situ images and video of live invasive mussel colonies on the lake bottom at 45 meter depth, along with water quality and currents, provide insight into mussel activity in the environment.

- The biomass and density estimates for Lake Michigan are viewed as extremely valuable among the Great Lakes research, education, and management communities that interact with the general public.
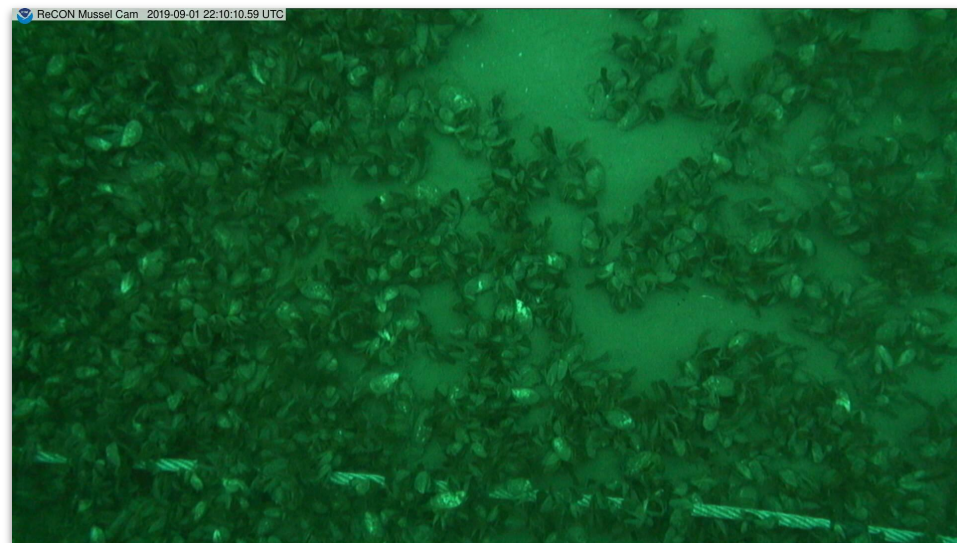


Video available on GLERL website
https://www.glerl.noaa.gov/res/recon/browsevideo-bio.php

**QUALITY:**
Assess quality of GLERL's R&D

# Award winning support of Lake Erie drinking water public safety.

Department of Commerce

Bronze Medal

2016 OAR Bronze Award: For response activities for the Lake Erie harmful algal bloom that impacted drinking water supplies in Ohio and Michigan

2017 NOAA Technology Transfer Award: For delivering a buoy that provides water managers with the critical information necessary to more effectively process compromised drinking water.

Scott Moegling, Water Quality Manager with Cleveland Water Department stated, "Our first priority is the health of our customers. We receive valuable and complex information in real time with these buoys. That data is an important addition to our treatment tool kit."

The GLERL Marine Instrumentation Lab team, left to right: Steve Ruberg, Kyle Beadle, Ron Muzzi, Terry Miller, and Steve Constant.

Cleveland Ohio water intake crib.

# An integrated approach to studying harmful algal blooms: Synthesis, Observations and Response (SOAR) Project.

**TIME SERIES BUOYS**

- Evaluate lake response to nutrient loads.
- Evaluate wind-driven nutrient resuspension response.
- Provide fine temporal resolution observations for biophysical models.
- Examine relationships between nutrient availability and toxicity.
- Provide real-time water quality observations to researchers and water intakes through GLOS.
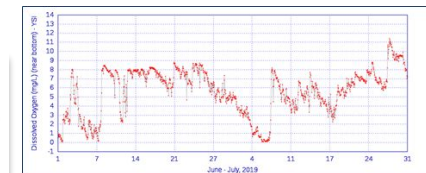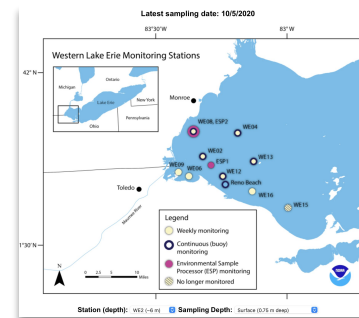


Continuous Parameters: Nutrients and Water Quality (Temperature, Specific Conductivity, Chlorophyll, Phycocyanin, Turbidity, FDOM, pH, Dissolved Oxygen)
Water Intake Year-Round: Waves, Currents, Ice Thickness, Backscatter, and Water Quality

**SPACE-BORNE SATELLITES**

Average HAB extent linked to nutrient reductions.
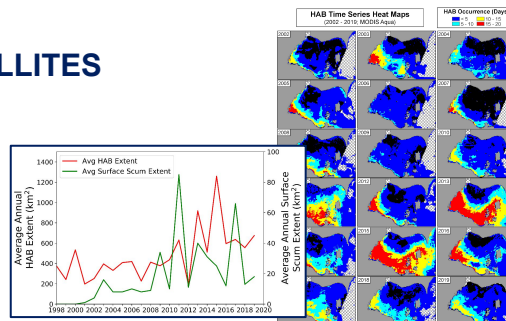


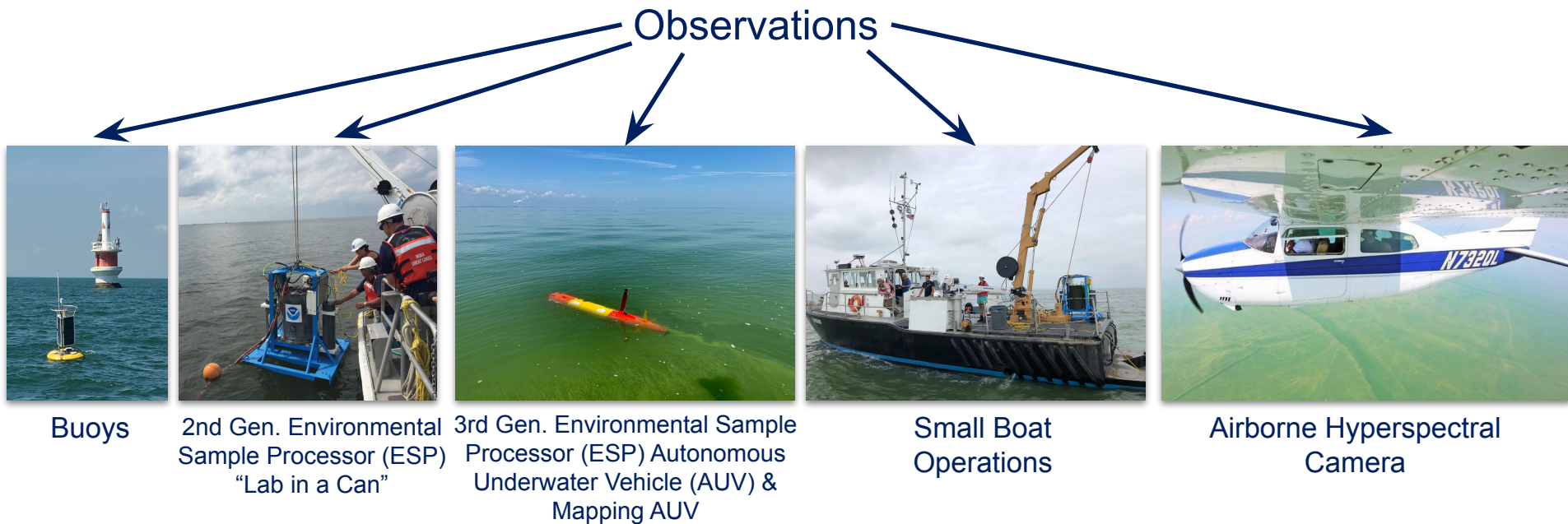**AIRCRAFT MOUNTED HYPERSPECTRAL CAMERAS - Detection of Cyanobacteria HABs**

24-28 hr Cyanobacteria Level Report to Ohio EPA, Ohio Municipal Drinking Water Managers, Michigan Drinking Water Managers, Michigan DNR.

Developing next generation NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Hyperspectral Satellite Algorithms.
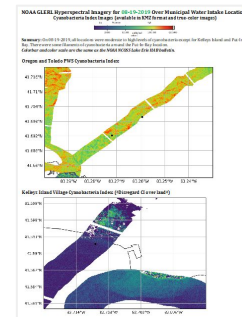


Rowland, F. et al., *Environmental Science and Technology*, 2020; Anderson, C.R. et al., *Frontiers in Marine Science*, 2019 ; Bosse, K.R et al., *Journal of Great Lakes Research*,2019 ; Moore, T.S. et al., *Remote Sensing of Environment*, 2019; Moore, T.C., et al., *Journal of Great Lakes Research*, 2019; Sayers, M. J. et al., *Journal of Great Lakes Research*, 2019; Moore, T.S. et al., *Frontiers in Marine Science*, 2017

# A collaborative effort for ecosystem forecasting & HAB detection

Observations



Buoys

2nd Gen. Environmental Sample Processor (ESP) "Lab in a Can"

3rd Gen. Environmental Sample Processor (ESP) Autonomous Underwater Vehicle (AUV) & Mapping AUV

Small Boat Operations

Airborne Hyperspectral Camera

# Developing and operating four continuous nutrient monitoring buoys in Western Lake Erie

- High frequency phosphate and nitrate measurement in addition to sonde and met
- Helps evaluate internal cycling of phosphorus due to wave driven resuspension
- Fills gaps between weekly sampling
- GLERL and Great Lakes Observing System (GLOS) portals serve real-time data
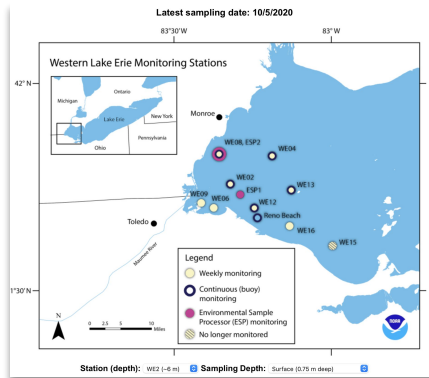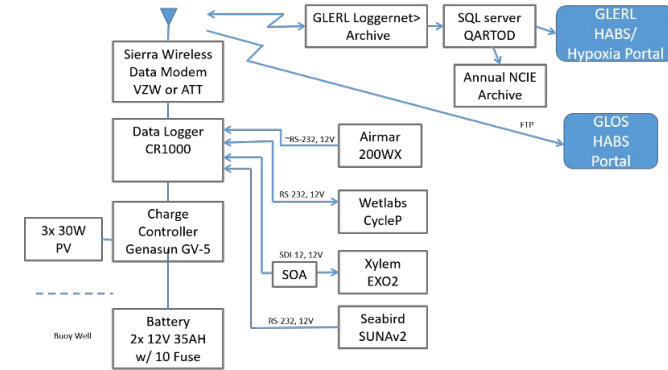




(Left) Heidi Purcell (CIGLR) deploys the WE4 buoy anchor to the bottom, July 2020.
(Right) Buoys carry phosphate, nitrate, Sonde instruments, serviced ~monthly.
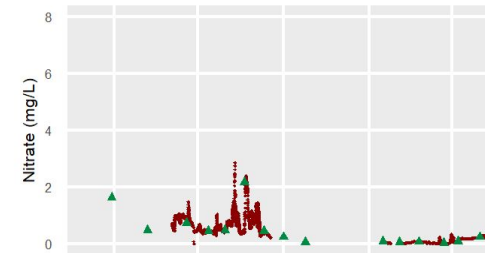
# Hyperspectral research fills in data gaps under clouds and nearshore areas.

New PIKA L sensor integrated into small plane system.



| | Resonon Pika II | Resonon Pika L |
|---|---|---|
| **Spectral range** | 400-900 nm | 400-1000 nm |
| **Bands/Channels** | 240 | 281 |
| **Field of View** | 17.6 degrees | 24.8 degrees |

| Great Lakes Hyperspectral Flights per HAB season | |
|---|---|
| 2015 | 8 |
| 2016 | 28 |
| 2017 | 30 |
| 2018 | 22 |
| 2019 | 20 |
| 2020 | 15 |

**Vander Woude** et al., 2019, *Journal of Great Lakes Research*.

Lekki, **Ruberg, Vander Woude** et al., 2019, *Journal of Great Lakes Research*.
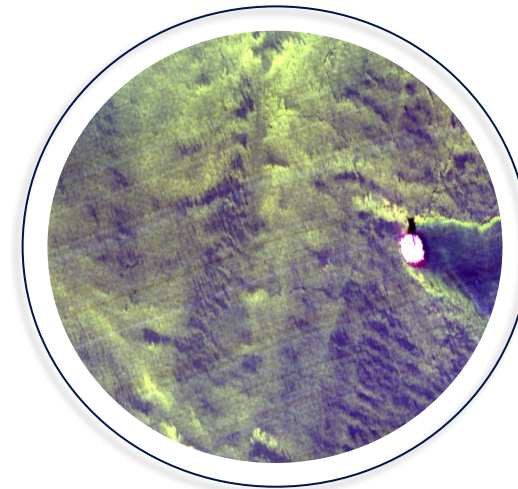
# Weekly airborne hyperspectral flights true-color imagery browser provides important information to drinking water managers.



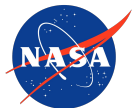Phytoplankton Community Composition (PCC) Algorithm
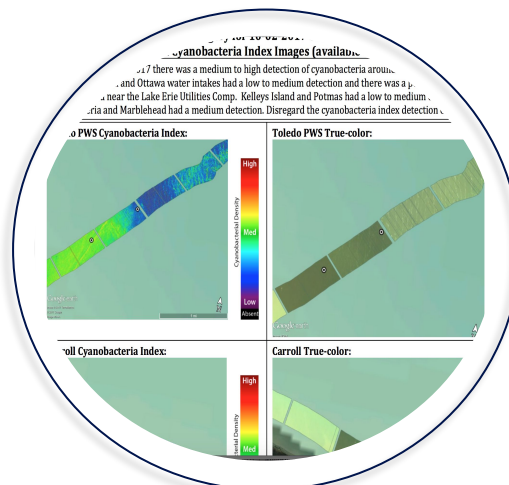


Phytoplankton Community Composition: Warn drinking water intake managers



**Successes**
- 6th year of flyovers,15 during COVID
- Flying a new camera this year
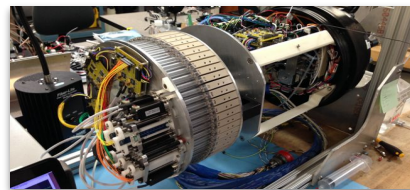- Integration into Forecast System
- PCC algorithm under completion

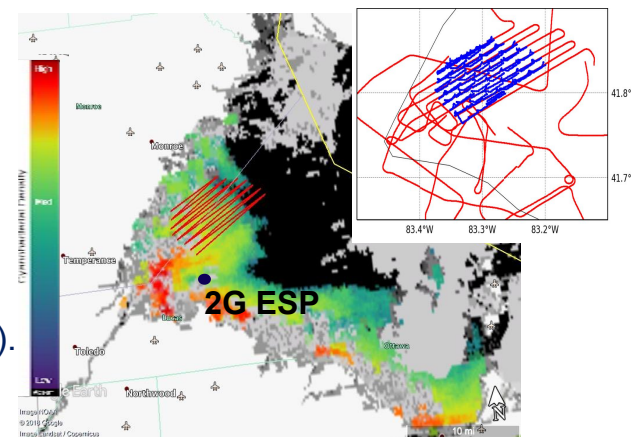Available at National Centers for Environmental Information (NCEI) 2021

# Using multiplatform observations directs adaptive HAB sampling strategies.

HAB Toxin Detection with Monterey Bay Aquarium Research Institute (MBARI) 3nd Generation Environmental Sample Processor (3G-ESP):

- Collaborative work to to demonstrate microcystin toxin sensor, DNA archive, and mapping capabilities (EcoDyn, NCCOS, AOML).
- Sentinel-3A Cyanobacteria Index product informed mapping AUV (Tethys).
- Tethys measured in-situ Chl fluorescence gradient.
- This informed the 3G-ESP AUV (Makai) to track and sample.



2G ESP

Future direction: Cyanobacteria Levels, Hyperspectral Imagery (red lines) and Mapping AUV Tethys (blue lines) Chlorophyll Concentrations.



Hyperspectral Cyanobacteria Index

While the LRAUV moves through the water the 3G ESP collects samples of water, filters them, and then processes the samples to detect microscopic organisms or toxins such as microcystin. After analyzing the samples, the 3G ESP can send its findings to scientists on shore via satellite link.
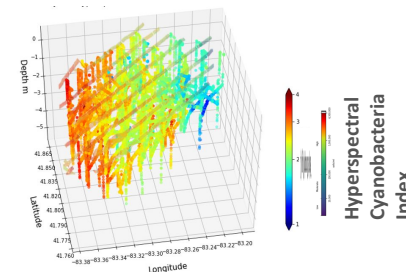
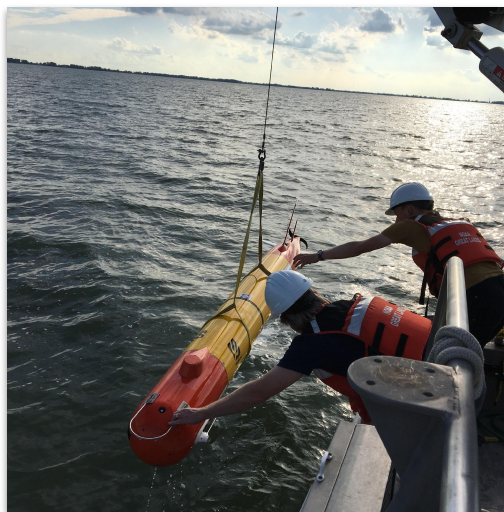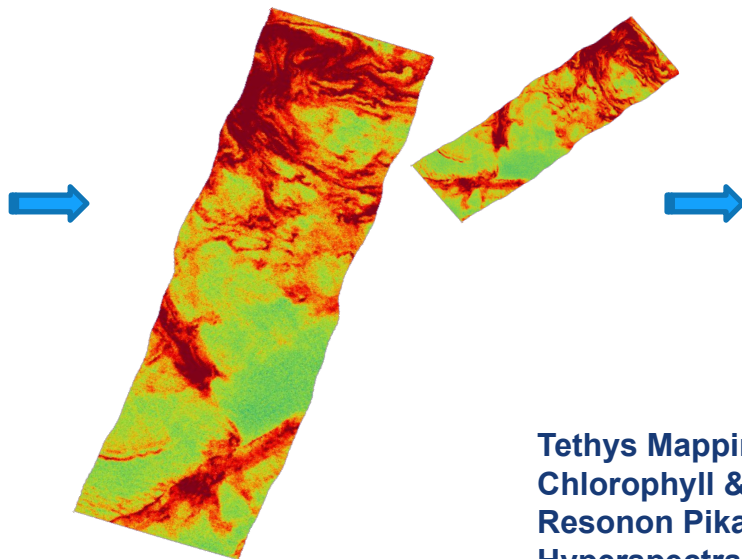**RELEVANCE:** Assess GLERL's R&D relevance to NOAA's mission & value to Nation

# Interactive 3D Combination of Hyperspectral and 3G AUV Data - Transition from Research to Operational Tools
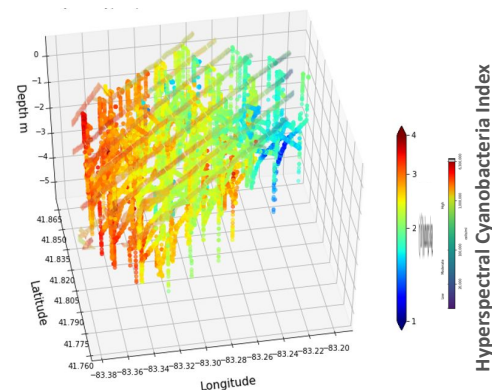
**3G LRAUV + Mapping AUV**

**Hyperspectral Imagery**



**Tethys Mapping AUV Chlorophyll & Resonon Pika II Hyperspectral CI Image**

**Vander Woude** et al., 2020 *American Geophysical Union Ocean Sciences conference.*

# The Great Lakes Evaporation Network (GLEN) provides key water level forecasting measurements.

**Stannard Rock**
- Environment and Climate Change Canada  / GLERL
- Comms/data transfer through GLERL's Real-time Coastal Observation Network (ReCON)

**Granite Island**
- Northern Michigan University

**Muskegon**
- Potential future GLERL station

**Toledo Light 2**
- GLERL (formerly University of Toledo, but GLERL funded to upgrade/replace all equipment)
- Comms/data transfer through ReCON

**White Shoal Light**
- Comms/data transfer through ReCON
- GLERL funded to replace/upgrade equipment

**Spectacle Reef**
- GLERL
- GLERL funded to replace/upgrade equipment

**Nine-Mile Point**
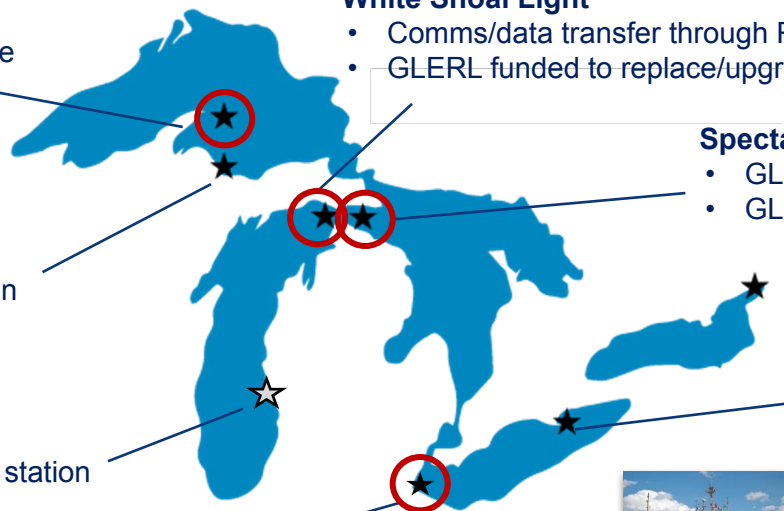- Environment and Climate Change Canada

**Long Point**
- Environment and Climate Change Canada

**Limnos**
- Environment and Climate Change Canada

**Whitefish Bay**
- University of Colorado

# Building an evapotranspiration network to better understand the interactions between ecosystem and hydrologic cycles.

Goal: Develop a network of open water flux observations for verification and calibration of evaporation in hydrodynamic and weather models.

Turbulent fluxes of latent and sensible heat flux measurements are important physical processes that influence the energy and water budgets of the Great Lakes.

These data are key for researchers to make water level, ice cover and lake-effect snow forecasts better.



Michigan Technological University
1885

University of Colorado **Boulder**

NORTHERN MICHIGAN UNIVERSITY

Environment and Climate Change Canada
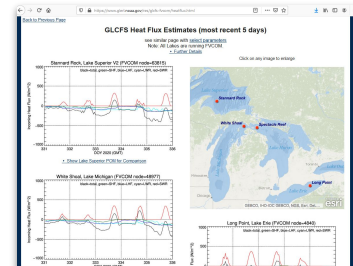
# Exploring submerged sinkholes: groundwater and microorganisms.

- Mapping and exploration
- Groundwater age & chemistry
- Microbial community
- Observe long term flow variability
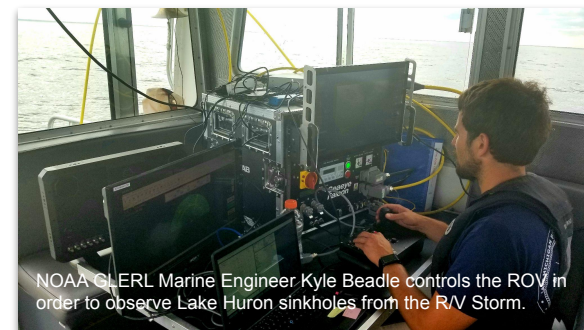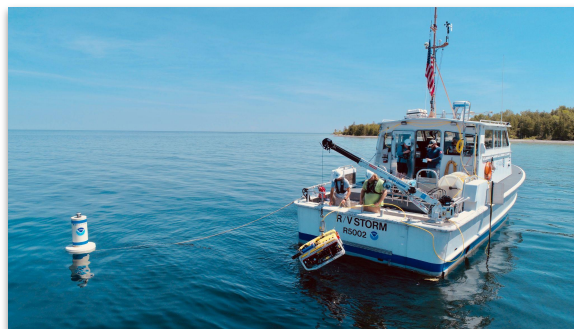




NOAA GLERL Marine Engineer Kyle Beadle controls the ROV in order to observe Lake Huron sinkholes from the R/V Storm.





Middle Island Sinkhole
(Modified from W.R. Lusardi)
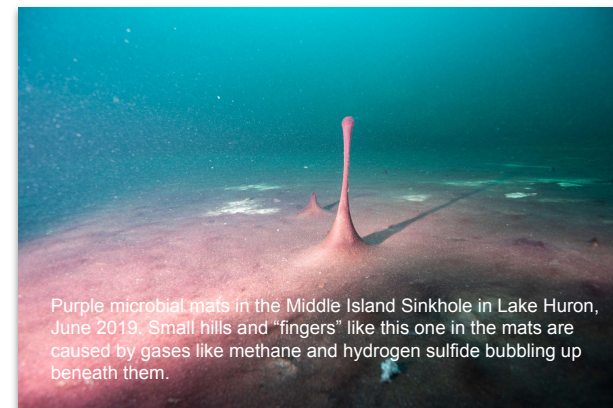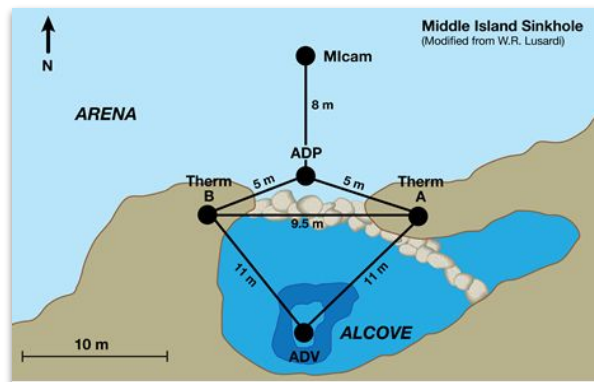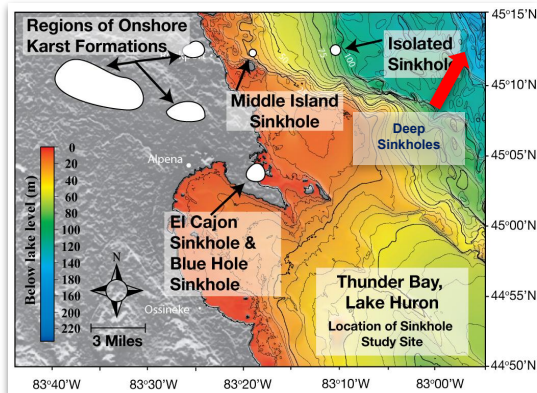


Purple microbial mats in the Middle Island Sinkhole in Lake Huron, June 2019. Small hills and "fingers" like this one in the mats are caused by gases like methane and hydrogen sulfide bubbling up beneath them.

# Fostering an environmentally literate society



Partnered with Great Lakes Outreach Media to create a short film entitled "Sinkhole Science: Groundwater in the Great Lakes." Featured on Detroit Public Television's *Great Lakes Now* program and at the NOAA Thunder Bay National Marine Sanctuary's International Film Festival. See video on review website.
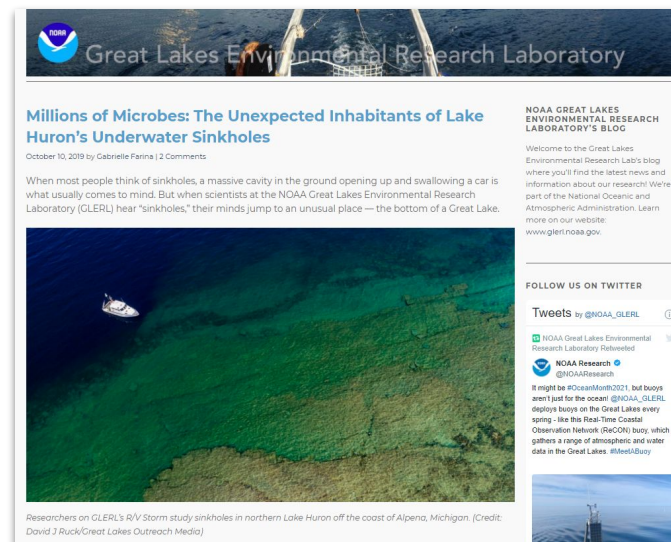


Check out the GLERL blog: https://noaaglerl.blog/

Baskaran, **Ruberg** et al., 2016, Aquatic Geochemistry
Sharrar, **Ruberg** et al., 2017, *Frontiers in Microbiology*

# Looking Forward

Steve Ruberg

# Looking forward: Ecosystem acoustic sensing systems for understanding the effects of stressors on zooplankton/nekton distributions and trophic interactions

Application of hydroacoustics to support long-term zooplankton, nekton, and HABs research (including winter observations)

- Apply multi-frequency hydroacoustics (70 - 766 kHz) using crewed vessels, uncrewed vessels, and fixed moorings, to map the abundance and spatial distributions of pelagic zooplankton and nekton, and subsurface distribution of HABs, in the western basin of Lake Erie and southwest Florida (red tide)*
- Apply multi-frequency acoustics using uncrewed vessels and fixed moorings to understand and quantity the spatial distribution and abundance of zooplankton and nekton during the winter months in the Great Lakes
- Supports GLERL's long-term research for understanding the effects of stressors on changes in abundance and spatial distribution of the pelagic community, and effects on trophic interactions.

*In collaboration with NOAA Atlantic Oceanographic and Meteorological Laboratory (Miami, FL)



Basic hydroacoustic concept.

# Looking Forward: Demonstrate Winter and Under-Ice Ecosystem Observational Capacity

Demonstrate the capability to navigate a Saab Sabertooth Autonomous Underwater Vehicle (AUV) from Lake Michigan Field Station through the Port of Muskegon pier heads to map invasive mussel reefs offshore using multibeam sonar and high-resolution imagery.

Application of suite of sensors (environmental and multi-frequency single beam acoustics) to measure water temperature, chlorophyll-a, zooplankton, and fish.

Demonstrate under ice with a fully integrated docking, charging, and data transfer station.
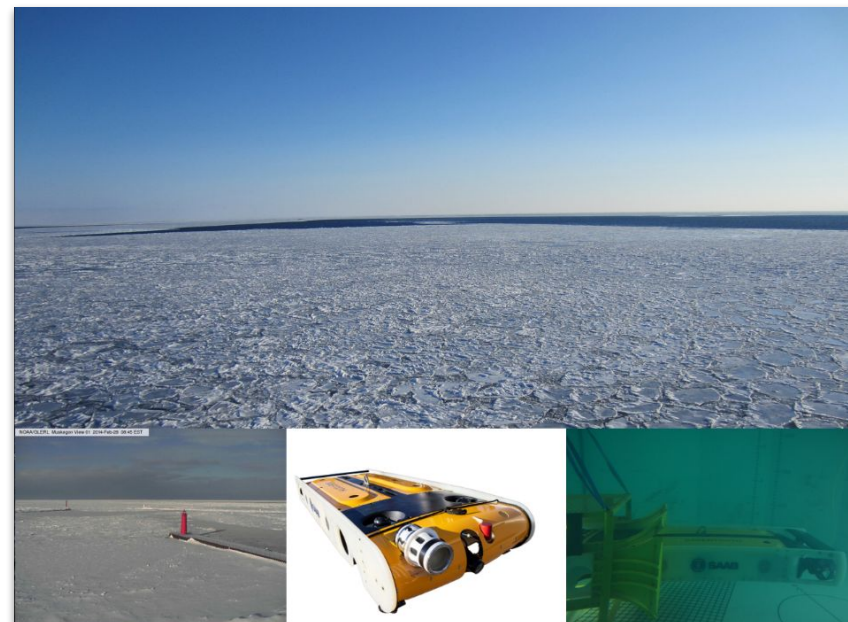
# Looking Forward: Great Lakes Meteotsunami Observations
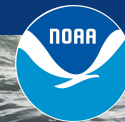
A cross-NOAA line office and cross-agency effort to develop a Great Lakes meteotsunami detection, forecast, and warning capability to protect the public from hazards associated with these conditions.

2021 deployed the first Great Lakes Deep-Ocean Assessment and Reporting of Tsunamis) DART buoy in southern Lake Michigan to detect meteotsunami signals.
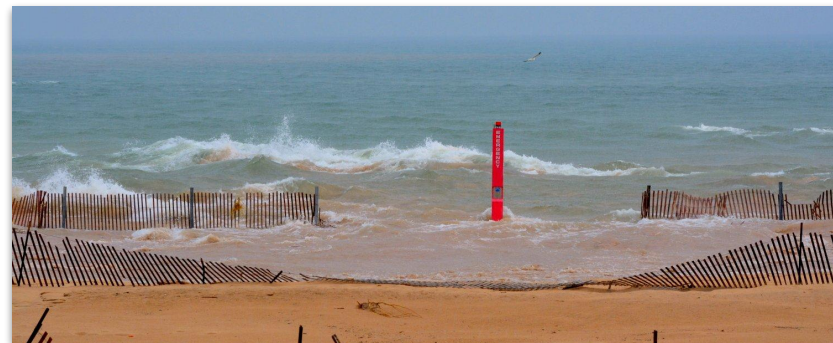
# Summary
Steve Ruberg

# In summary, OSAT. . .

Advances remote sensing, autonomous vehicles, and coastal data-gathering technologies that provide a strong foundation for research in the Great Lakes and other coastal communities

Provides observations and data on the physical, chemical, and biological components of the Great Lakes and coastal ecosystems to support studies and assessments, informs experiments and models, and ultimately predictions and forecasts.

Develops, tests, evaluates and implements emerging technology advancements in data collection, striving to improve NOAA's observational capabilities to better understand ecosystem processes.

Supports research by providing safe and capable multi-disciplinary research vessel platforms to study the Great Lakes by deploying instruments, collecting samples, conducting surveys, and supporting autonomous/uncrewed systems and remote observation stations

## OSAT works to achieve NOAA's mission by . . .

Conducting award-winning scientific and engineering research and development.

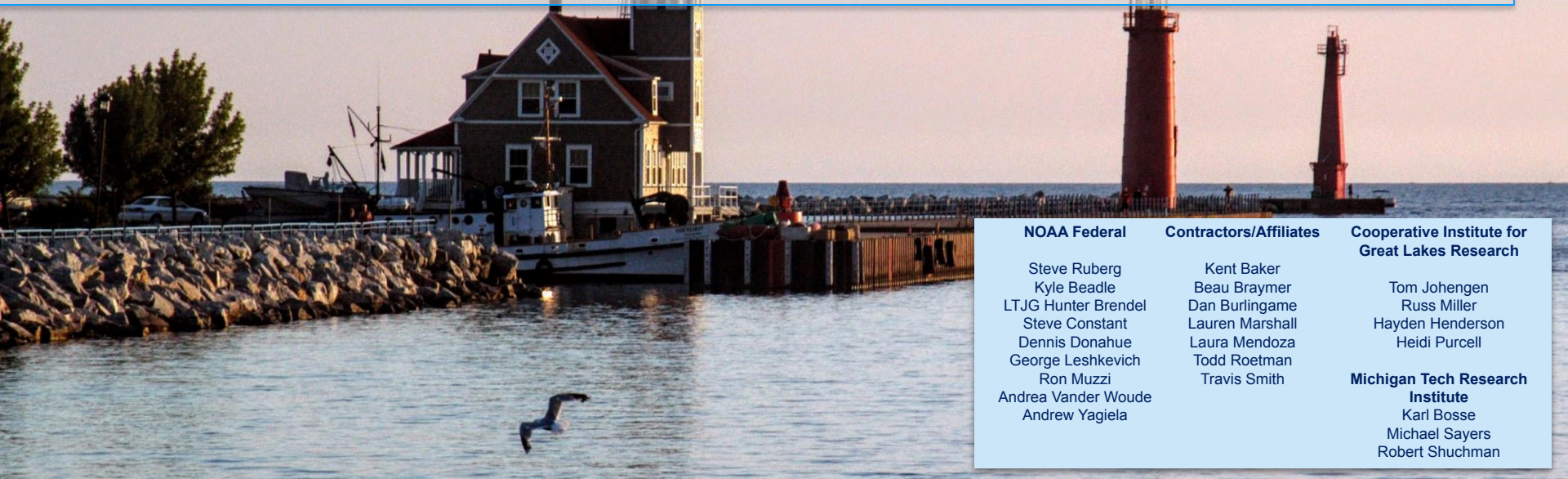Looking toward the future by identifying emerging infrastructure needs.

Leading observing technology innovation.

Providing environmental observations and data throughout the Great Lakes.

# Thank you for your attention!

| NOAA Federal | Contractors/Affiliates | Cooperative Institute for Great Lakes Research |
|---|---|---|
| Steve Ruberg | Kent Baker | Tom Johengen |
| Kyle Beadle | Beau Braymer | Russ Miller |
| LTJG Hunter Brendel | Dan Burlingame | Hayden Henderson |
| Steve Constant | Lauren Marshall | Heidi Purcell |
| Dennis Donahue | Laura Mendoza | |
| George Leshkevich | Todd Roetman | **Michigan Tech Research Institute** |
| Ron Muzzi | Travis Smith | Karl Bosse |
| Andrea Vander Woude | | Michael Sayers |
| Andrew Yagiela | | Robert Shuchman |

# Thank you for agreeing to serve as a member of the GLERL five-year science review panel!

We look forward to talking with you during the live Q & A sessions.

**Review criteria:**
Quality: The merit of our research and development within the scientific community.
Relevance: The value of our research and development to users beyond the scientific community.
Performance: The effectiveness and efficiency with which our research and development activities are organized, directed, funded, and executed.

**Review week highlights:**
- In-depth Q&A/discussions of the overview presentation each theme presentation.
- Meetings with GLERL stakeholders.
- Meetings with GLERL leadership and new staff.

**All supporting documents can be found on the GLERL 2021 Review website at:**
**www.glerl.noaa.gov/review2021/#documents**